

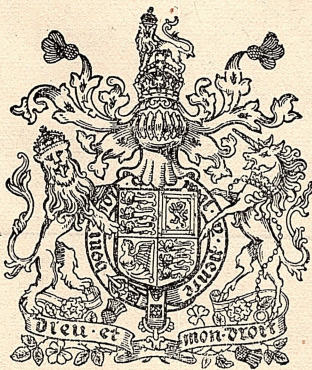
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STATISTICS

COMMITTEE ON EDUCATION AND RESEARCH IN AERONAUTICS.

REPORT.

Presented to Parliament by Command of His Majesty.



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AIR MINISTRY.

**COMMITTEE ON EDUCATION AND RESEARCH
IN AERONAUTICS.**

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SIR ALFRED KEOGH, G.C.B., G.C.V.O., C.H., Imperial College of Science and Technology.

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COMMITTEE ON EDUCATION AND RESEARCH IN AERONAUTICS.

REPORT OF THE COMMITTEE.

To the Right Hon. Winston S. Churchill, M.P.,
Secretary of State for Air.

1. The Committee on Education and Research in Aeronautics was appointed originally by Lord Weir of Eastwood, in October 1918, under the following terms of reference :—

“To consider what steps should now be taken to organise education and research in aeronautics after the war, and to report.

The Committee should have regard to the agencies which already exist for this purpose, or which it is proposed to establish, and in particular the relationship of the Zaharoff Professorship to such agencies.”

At a later date, after learning the views of the Committee, the Government came to certain conclusions with regard to the matters under consideration, and the Committee was requested, in November 1919—

“To consider and report with reference to the decisions of the Government as to Aeronautical Research, Education, &c., and to submit recommendations.”

In accordance with this reference the Committee proceeded to consider what steps should now be taken to organise education and research in aeronautics in view of the decisions referred to above, of which the main features are as follows :—

(a) The responsibility for research and experimental work undertaken for the development of aeronautics with money provided by the Government will be shared by the Department of Scientific and Industrial Research and the Air Council. To assist the Air Council in their work an Aeronautical Research Committee is to be constituted in substitution for the present Advisory Committee for Aeronautics. The exact composition and functions of this Committee have not yet been decided.

(b) The assistance to be given by the Department of Scientific and Industrial Research to research and experimental work in aeronautics is to be on the same lines as that given in other industries, *i.e.*, if the aeronautical industry desires at any time to form a research association for the purpose of conducting research into some special phase of aeronautics, the Department has authority, after consulting the Air Council with a view to preventing overlapping of work, to finance such an association for the purpose.

(c) The main part of the financial assistance to be given by the Government to the study of aeronautics will, in view of the foundation of the Zaharoff Chair of Aviation at the Imperial College of Science and Technology, be given to that College, but application for assistance from other Universities in future, should they require it, will also receive consideration.

Taking these decisions into account, and considering the question in all its aspects, the Committee has come to the conclusions set forth in the following Report :—

INTRODUCTION.

2. The Government have now decided how provision is to be made for research in aeronautics. We desire, at the outset, to emphasise the necessity for that research.

The Department of Scientific and Industrial Research is to continue the provision for fundamental research at the National Physical Laboratory, and to assist the Aeronautical Industry in the same manner as other industries, by taking part, when desired, in the formation of a Research Association. In our view, at the start of a new industry, something more is required. At the present moment the industry is passing through a crisis ; Government support is necessary if it is to emerge satisfactorily.

The time is critical and the development of civil aviation is beset by numerous difficulties and calls for the fullest consideration. It is urgently necessary that the policy adopted should command the support of all who desire to maintain the superiority in the air gained during the past eventful years, and that ample funds should be provided for carrying it into effect.

3. A difficulty which arises in the case of a new industry of this kind lies in the fact that the scope of the work is inadequate to maintain automatically a sufficient number of experts in design and production.

A research organisation may elucidate problems, provide general information and specific facts, but before these can bear fruit of industrial value they must be interpreted and applied by a suitable technical staff, closely associated with the Works organisation. At the end of the war most of the works had collected a team of technical experts of marked ability; many of these teams have now been disbanded and further disintegration is in progress. We see no possibility of achieving the desired result except by such Government action as will secure the retention of adequate technical staffs.

4. During the war this country obtained the lead in aeronautical research; it would be lamentable to see the fruits of the work pass from a paralysed industry to better supported foreign competitors. In the later sections of our Report we recommend the establishment of an organisation for Aeronautical Research to assist the Air Council, and, in our view, it is important that the work of that organisation should be available, in great measure, for the assistance of the Industry and the advance of Civil Aviation, as well as for the Services. Should an Industrial Research Association be formed, it should be linked up with the organisation we recommend.

5. Education and research are clearly very closely interrelated. The education with which we have chiefly concerned ourselves is that suitable for Aeronautical Engineers and Constructors, that is to say, post-graduate work for which the students will be fitted by a previous undergraduate course of either mechanical or general engineering training at one of the Universities or Technical Colleges. We have not dealt with the training of pilots or of mechanics. The course we contemplate will comprise a special study of the following matters:—Aerodynamics—the laws of motion of bodies moving in the air, illustrated by experiments and researches in wind channels; the principles of design and construction; engines and the methods of propulsion of aircraft; the investigation of instruments used in flight, with problems in Meteorology and Navigation. The engineer must also gain the practical knowledge acquired only in the workshop, and must have experience of the full scale researches necessary to test and verify his theoretical conclusions. Such a course might eventually involve one or more centres of theoretical instruction with experimental aerodromes and laboratories where the full scale problems may be worked out, but as the number of persons likely to require this higher post-graduate education will not be great, we consider that it will be wise for the present to concentrate the work in one central institution with which the experimental aerodromes should be closely connected. Such a central institution we find in the Imperial College of Science and Technology at which the Professorship lately founded by Sir Basil Zaharoff, G.B.E., is to be held.

6. To turn now to Research: this is the means by which advance in aeronautics is possible and it is required by all interested in the progress of the subject; by the State, whether for the purposes of defence or to enable it to lay down the rules necessary for the safety of aircraft when used for civil purposes; by the Professor whose aim is to increase knowledge, and by the Industry in order that they may maintain the superiority which British aircraft has already achieved. Research is difficult, its requirements are costly, and the men who can undertake it are few. To establish separate research laboratories and aerodromes for each of these special interests is for the moment out of the question; here again combination is called for; combination too with the agencies concerned in education. At the same time we recognise fully that special problems may be dealt with at other research centres, and we trust that every encouragement may be given to these for such work.

7. Since the commencement of practical aeronautics, research has been directed by the Advisory Committee for Aeronautics, a body under the presidency of the late Lord Rayleigh appointed by the Prime Minister in the year 1909, "for the superintendence of the investigations at the National Physical Laboratory and for general advice on the scientific problems arising in connection with the work of the Admiralty and War Office in aerial construction and navigation."

8. Full scale research has been carried out at Farnborough in part at the initiation of the Advisory Committee, in part at that of the military authorities; the Committee, however, have no control over the work there and only occupy an advisory position with regard to it. During the war other centres of full scale research were established, *e.g.*, the Isle of Grain and Felixstowe for Seaplanes, Kingsnorth and

Pulham for Airships, and the Advisory Committee has been kept in close touch with the work in progress at all of these. Its activities have been of the greatest value. In our view a central co-ordinating body of this kind is essential, and it is now proposed to establish an Aeronautical Research Committee to which the duties of the Advisory Committee would be transferred, and to which would be added certain duties and responsibilities with regard both to the central research aerodromes and to education. The proposed Committee should be in a position to supervise effectively such work as comes within its purview.

9. The work in Aeronautics conducted at the National Physical Laboratory would also, usually, be undertaken on the initiation of the Committee, the expenditure for such work forming part of the budget of the Department of Scientific and Industrial Research.

10. In order to connect the Committee with the educational work and to render the opportunities of research at Farnborough and elsewhere available both to teachers and to students, we suggest that arrangements should be made between the Committee and the Imperial College for dealing with matters with which they are jointly concerned. In this connection, moreover, we suggest that it would be possible in a number of cases for members of the Research Staff to act as Professors or Lecturers at the College.

The scheme outlined above, which we proceed to develop more completely, agrees in the main with that put forward in the Reports of the Civil Aerial Transport Committee (Cd. 9218) and described in the reports of Special Committee No. 5, and we consider that it may be possible through the organisation outlined to link up the advanced teaching in aeronautics wherever given. It is, in our opinion, highly desirable and indeed essential that any teaching connected with aeronautics which may be given elsewhere should be related and co-ordinated with this organisation.

We would add that the reports of Special Committee No. 5 of the Civil Aerial Transport Committee have been of the greatest value to us.

EDUCATION IN AERONAUTICS.

11. Education in aeronautics in its widest sense might be held to cover not only the education of the scientifically trained engineer, designer, or constructor, but also that of the mechanic or artisan. We have not, however, thought that the education of the latter class fell within our terms of reference. It will in the main be provided by the formation of special classes at the principal technical schools, more especially at those situated in the neighbourhood of important works or aerodromes.

12. The problem of the organisation of education in aeronautics as it has presented itself to us has been that of higher education, which can only be given in institutions of university rank.

The subject-matter of this higher education comprises instruction in—

I. Aerodynamics—

(a) Aeroplanes

(b) Seaplanes

(c) Airships and Kite Balloons

} Full scale and model work.

II. Engines and the means of propulsion.

III. Principles of Design. Structure and Material.

IV. Instruments, Meteorology, and Navigation.

13. We consider that an undergraduate course in engineering such as is commonly provided at Universities and at the great Technical Schools forms the necessary preparation to any more specialised courses of instruction.

The advent of aeronautics will doubtless to some extent be reflected in the *curricula* of existing undergraduate courses. Just as at present the education of a mechanical engineer is incomplete without some general knowledge of electrical engineering, so in future all engineers should have at least an elementary knowledge of aeronautical engineering. For the civil engineer it will, for example, offer some instructive instances in the study of structural design while some reference to aeronautical engines will necessarily form part of any mechanical engineering course. Existing courses do not, however, provide for the specialised training which is needed for those who are to direct aeronautical research, and the design and construction of aircraft. It is clear that the provision of such training is of vital importance to the future of aeronautics whether viewed from the industrial and civil standpoint or from the point of view of defence.

14. The organisation of this higher training requires, in our view, the provision—
- (a) of courses for men who have attained the highest standards of university training at the various engineering schools;
 - (b) of courses based on a sound general engineering training but not involving too high a standard of mathematical knowledge for men of special practical ability.

The first class is represented by honours graduates, *i.e.*, by the pick of those who have passed through undergraduate courses.

We contemplate that the period of special theoretical training should not exceed 12 months, distributed as might be convenient over the ordinary period required for practical training.

During the period of post-graduate instruction the student should also obtain some air experience. We have not, however, thought it within the scope of our inquiry to deal with the question of the provision of instruction in flying, though it is, we think, important that it should be recognised as a desirable part of the technical equipment of the designer and constructor.

We have not thought it necessary to work out in detail the *curricula* of the higher education nor to discuss the administrative arrangements which will be required to provide for the division of the student's time between the lecture courses and the practical work in research stations or in the shops.

15. It is undesirable that promising students of small means should be deterred from higher education in aeronautics by the expense which a prolonged period of training involves. An adequate system of maintenance scholarships should be established. This might be supplemented by the payment of small salaries in respect of periods passed in the research establishments or in aircraft works.

Organisation of the Higher Education in Aeronautics.

16. The specialised or post-graduate training of the kind which has been described in the previous paragraphs should, in our view, be organised on an entirely different basis from the undergraduate training. The latter as we have shown can and should be provided in existing organisations of University rank in various parts of the country. Post-graduate training, however, to be complete, requires access to aerodromes and to research stations fitted with technical equipment, and it would be, we think, impracticable under present conditions to try to provide completely for this highly specialised training at more than one centre.

The financial saving through the avoidance of duplication of research and other facilities necessary to the higher grades of education is obvious. It is also relevant that whatever the future developments of air transport may be, the number of posts for which men of the higher standard of training are required will be limited; and that men possessing the combination of theoretical aptitude and practical ability needed to profit by the highest kind of professional training are not numerous. Before the war the total yearly number of honours graduates in engineering, including civil, mechanical, electrical engineering and naval architecture, from all the Universities in the United Kingdom was not high, and only a fraction of the future number are likely to devote themselves entirely to aeronautics.*

17. In connection, however, with the question both of undergraduate and post-graduate education we would remark that the demands for the courses provided must depend considerably on the policy of the Government for the filling of such higher technical appointments as may be required by the Air Force or by the Air Ministry, or whatever Department becomes responsible for the regulation of civil aviation. If technical appointments are thrown open to competition among graduates (as is done, for example, with the medical branches of the Naval and Military Services) the demands for the training provided in the University courses will be greater than if the State itself trains youths selected at an early age.

* *Vide* paragraph 24 of the Final Report of Special Committee No. 5 of the Civil Aerial Transport Committee :—

As outlined above, the specialised training of the aeronautical engineer would be a post-graduate course, and the question arises as to the nature of the institutions at which such courses should be organised. It has already been pointed out that, whatever the development of the industry may be, the number of posts suitable for men of the highest standard of training is necessarily limited, and it is equally obvious that men possessing the combination of theoretical aptitude and practical ability required to profit by such a training are not numerous. Before the war the total yearly number of honours graduates in engineering, including civil, mechanical, electrical engineering, and naval architecture, &c., from all the universities in the United Kingdom averaged about two hundred.

18. The Zaharoff Professorship of Aviation supplies the nucleus of the single organisation which we think is desirable for the direction of higher education in aeronautics. This Professorship was established as the result of a benefaction to the British Government by Sir Basil Zaharoff, G.B.E., and it has been arranged between the parties concerned that it should be established as a Professorship of the University of London and held at the Imperial College.

In our opinion the Imperial College should become the Central school for advanced study in aeronautical science, and we have, in the later sections of the report, described an organisation for teaching and research whereby this might be secured.

19. It is clear that it would exceed the powers or abilities of any single teacher to cover all or many of the various fields of knowledge which are comprised under the general term of aeronautics. The appointment of additional teachers and the organisation of the Department of Aeronautics should be effected with the fullest regard to the resources which the Imperial College already possesses for providing instruction in interdependent subjects such as Physics, Mathematics and Engineering.

20. The teaching personnel of the actual Department of Aeronautics should, we think, comprise professors or lecturers qualified to provide advanced instruction as regards aeroplanes, seaplanes, airships, and kite-balloons in the following subjects: (1) aerodynamics, *i.e.*, the laws of motion of bodies moving in the air, (2) aero-engines and methods of propulsion, (3) design, including structure and materials in so far as these could not be treated apart from the principle of design of aircraft in the Engineering and other departments of the College, (4) meteorology, instruments and navigation.

21. We consider that it is of importance that the same staff should to a great extent deal with both education and research, including much of the research directly required by the Government as well as that directed more especially to the advancement of the theory of flight. The expense involved in aeronautical research and the limited number of men competent to undertake it both lead to this result, which is in our view in itself desirable. We discuss this question in greater detail in Sections 49-52 of our Report.

RESEARCH IN AERONAUTICS.

22. The establishments which will be required to provide the facilities for the different aspects of research in aeronautics fall under five divisions:—

- (1) Model Research;
- (2) Full Scale Research;
- (3) Testing and Experimental Investigation;
- (4) Special Investigations connected with Airships and Kite-balloons;
- (5) Navigation and Meteorology.

Model Research.

23. This includes model work in connection with aeroplanes, with seaplanes and with airships (rigid and non-rigid airships and kite-balloons). The model research work under these heads is at present carried on at the National Physical Laboratory and also to some extent at the Royal Aircraft Establishment.

The fact that under the arrangements we propose research work at the National Physical Laboratory and the Full Scale Research Establishments will be undertaken in co-operation with the Aeronautical Research Committee should remove any lack of touch which might exist between those responsible for model work and those conducting full scale investigation. The National Physical Laboratory also contains facilities for research in allied sciences.

Full Scale Research and Experimental Investigation.

24. This work comprises research undertaken to investigate general principles and laws and is at present mainly represented by the experimental side of the Royal Aircraft Establishment. During the war full scale research on seaplanes was mainly conducted by the Technical Department of the Air Ministry at the Isle of Grain and at Felixstowe, that on airships by the Admiralty at Kingsnorth and Pulham, while kite-balloons were investigated at Roehampton.

The Royal Aircraft Establishment and the aerodrome attaching to it are Government property, and it appears to us that suitable provision might be made either there or possibly at some other aerodrome near London for the full scale work which is essential to our scheme. Adequate facilities for the scheme already exist at

Farnborough along with other facilities for production work. We therefore recommend that such portions of the establishment as are required for our purpose should be made available for researches, under the supervision of the organisation described in the Report.

Under such an organisation the research work at the Royal Aircraft Establishment should, we suggest, come under the following heads:—

- (a) Experimental work for the advancement of aeronautics generally. The results should have open scientific publication, and participation in the experimental work should be among the educational facilities available at the establishment.
- (b) Specific experimental work undertaken at the request of a Government department. The publication of the results of the work would be a matter for the Government to decide.
- (c) Certain specific experimental and testing work on payment for the industry.

The establishment at Farnborough could not, of course, meet completely the need for full scale research and experiment on seaplanes and on airships, much of which must continue to be carried out elsewhere. But while this is so, there are many problems common to all kinds of aircraft which could be dealt with at Farnborough.

Special Investigations connected with Airships and Kite-balloons.

25. Full scale work on airships has been mainly carried on at Pulham Air Station, while kite-balloons have been dealt with at Roehampton, the model work, as in the case of aeroplanes and seaplanes, having been mainly done at the National Physical Laboratory. Here again arrangements must continue for full scale work to be carried on at some station possessing suitable facilities. Arrangements could, no doubt, be made for such investigations to go on under the supervision of the Research organisation.

Navigation and Meteorology.

26. The administration of the Meteorological Office has recently been placed under the Air Council, and we are glad to learn that the revision of the arrangements for the meteorological services which has now been carried through will be to the advantage of aviation, not only in respect of the collection and dissemination of meteorological information, but also in the furtherance of meteorological research.

The study of navigational problems, it may be remarked, has not been developed by the war to the same extent as some other aspects of air technology. The increasing range of air travel serves to emphasise the needs for the fullest development of experiment in these directions, and the introduction of aerial transport on a civil basis will greatly enlarge the demand upon both practical and theoretical meteorology.

Testing and Experimental Investigation.

27. This class of work, as apart from that referred to in Section 24, is at present represented by Martlesham Heath. It includes the determination of the performance of machines, tests of the efficiency of particular engines, and of minor modifications of machines and engines as affecting efficiency. This class of work may also include testing of typical machines to conformity with specification, as well as strength testing to destruction. A station of this character is required in view of the provisions of the Air Navigation Act.

Interests concerned in Research.

28. We now turn to an enumeration of the different interests concerned in the conduct of aeronautical research—in varying degrees but in all cases to a sufficient extent to require some voice in its control. They are (a) the State as responsible for the maintenance of the armed Forces of the Crown by land, sea, and air; (b) the Aircraft Industry as constructors and as operators; (c) Education—and in particular the organisations providing higher education; and (d) the State as the regulating authority for civil aerial transport.

Military Interests of the State.

29. The scope of the State's responsibilities will be based on the future requirements of national defence, and it is probable that the aerial defence of the country

will not be less important than naval and military defence on sea and land. Under present conditions, however, there is nothing to suggest any basis of expenditure on fighting aircraft either absolute or in proportion to expenditure on the Navy and Army.

30. We desire, however, to refer to one factor which seems to us of the first importance in the determination of the State's responsibilities as regards provision for research. In the pre-war Naval Estimates between one-third and one-half of the total vote was allocated to new construction, research and experimental work forming only a small incidental item. The larger naval units take a number of years to build. For that reason only a relatively small increase of effective construction can be brought about after a declaration of war; and supremacy, other things being equal, would be decided by the number and quality of the units available at the outbreak of hostilities. In the case of aircraft, however, the experience of the present war has been that a given type is becoming obsolete by the time that it is in general use. This applies essentially to the fighting scout machines, in a lesser degree to other types, and least of all to airships.

Regard must also be had to the high rate of wastage of aircraft under war conditions. There is, moreover, the liability of machines kept in store to become unfit for use, which makes it difficult (apart from financial considerations) to maintain a large peace reserve of machines.

The final supremacy in the air in any future war will thus depend not mainly on the number of units available at the outbreak of hostilities, but on the adequacy of the preparation made beforehand for the rapid construction of the newest and best types.

31. This preparation, so far as it might take the form of administrative arrangements for the maintenance of equipment for large emergency production, is not within the terms of our reference, but it is clear that such preparation must in any event imply the ordered availability of (a) general scientific knowledge accumulated by systematic research, (b) detailed information with regard to all available types, (c) a liberal construction (not necessarily by the State itself) of experimental machines.

It is relevant also to observe, in connection with the organisation both of research and education, that any emergency expansion of production which might be required by a future war must be directed by a body of technical experts who could not be improvised after the emergency had arisen.

The Aircraft Industry as Constructors and as Operators.

32. Economic and Imperial considerations alike emphasise the importance of securing that the aircraft industry of this country should be so organised as to maintain a supremacy against all competitors from other countries, and it is obvious that generous provision for scientific research is necessary for the efficiency of an industry so highly technical and scientific as that of aircraft construction.

It is, however, improbable that individual firms of designers or constructors could provide themselves with the research facilities which will be required. This is clear both from considerations of expense and of the insufficiency of men competent to undertake research work. The conduct of research on an individualistic basis, even if it were otherwise practicable, would involve a great deal of overlapping, and though it might enable individual firms to compete with each other, would not necessarily or even probably secure that their scientific resources would be organised in the best way to meet competition in international markets.

33. The formation of an Industrial Research Association, which is under consideration, implies a recognition of these facts. Such an organisation, which should embrace within its membership all the leading firms of aircraft constructors, is, in our view, essential to the conduct of research in the industrial aspect.

Education.

34. Access to research facilities is required (a) to enable the Imperial College to discharge its responsibilities for higher education in aeronautics and allied branches of knowledge, and (b) for the furtherance of knowledge as an end in itself and without reference to any immediate needs, whether of the State or of the industry. It is not necessary for us to labour the importance of adequate provision for independent research of this kind, but we desire to make clear our opinion that it is essential to the progress of knowledge in aeronautical and the allied sciences. During the war

purely theoretical investigations have inevitably been subordinated to those undertaken for war requirements. It is important that under peace conditions disinterested research should have proper scope.

The State as regulating Authority of Civil Transport.

35. It appears from the terms of the Air Navigation Act that the State as a regulating authority has powers, *inter alia*, to test and pronounce upon the airworthiness of machines in use for public purposes (that is to say, for carrying for hire or for the transport of mails). These functions imply the laying down of conditions of strength, performance, and air endurance, and it is necessary that the department exercising them should have access to research facilities.

Common use of Research Establishments by the various Interests.

36. From the foregoing paragraphs the conclusion has been reached that four different interests, each in its degree, require access to establishments where the types of research mentioned in Sections 22-26 are carried out, *i.e.*, (1) Model Research, (2) Full Scale Research, (3) Testing and Experimental Investigation, (4) Navigational and Meteorological Research.

37. We are of opinion that so far as possible the research facilities should be organised on the basis of a common use of the same establishments by the various interests.

We are led to this conclusion, as we have already remarked, by the need of conserving and utilising to the fullest degree the resources both in staff and equipment engaged in aeronautical research, and also by the fact that very great and, as it seems to us, unnecessary expenditure would be involved by any present duplication of research establishments.

The expenditure required for the provision and maintenance of the various establishments will be very considerable. A Model Research Establishment involves the provision of wind channels and laboratory equipment. Full Scale Research implies unfettered access to a completely equipped aerodrome with large engineering workshop facilities. The same applies to testing work. Navigational and Meteorological Research, too, cannot be efficiently maintained without expenditure on a liberal scale.

Limitation of the number of establishments is imposed not only by the desirability of avoiding a dissipation of effort, but also by the comparatively small number of persons who are at present qualified to direct the higher branches of education and research in aeronautics.

38. The principle of a common organisation of research stations is, however, subject to certain qualifications.

(a) Many researches of exclusively naval and military concern (such as, for example, armament research) must no doubt to a considerable extent continue to be carried on at service stations by service personnel, though assistance in particular problems should be available from the various establishments for research in aeronautics and in other allied branches of knowledge.

(b) It will be necessary to provide that the use of common facilities does not of itself imply the complete pooling of results. (i) This must necessarily apply as regards confidential investigations undertaken for Government purposes; (ii) it may also be found desirable to make arrangements whereby individual firms of aircraft constructors will be able to have industrial experiments carried out for their private information. The arrangements under which this will be done should be settled between any Research Organisation set up and the Industrial Research Association as representative of the industry.

(c) We think it is of importance to encourage decentralisation of research on aeronautical problems which do not demand elaborate equipment or involve actual flying. There are many branches of research of the first degree of interest which do not involve access to aerodromes or to elaborate aeronautical equipment, and which can therefore be carried on in other institutions. These include, for example, the study of raw materials (timber and fabrics), strength investigations of parts of structures, improvements in fuels, engine investigations, the chemistry of dopes, and mathematical investigations of all kinds.

Control of Research Facilities.

39. The maintenance of a common use of the same research facilities by the various interests concerned depends on the contrivance of a form of control of these

facilities which will command the confidence of all parties. We have come to the conclusion that it will be necessary for this purpose to set up a Research Organisation representative of the various interests, including the Industry and the Teaching Authority.

We recommend that this Organisation should take the form of an Aeronautical Research Committee, reporting to the Air Ministry. The Committee would supervise such research work for the Government as might be placed in its charge, and initiate such work as it thought advisable. Any work undertaken for the Committee at the central stations of the Ministry would naturally be carried out with the concurrence of the Director of Research. The Committee would also administer the funds made available by the Air Council for its work, and keep in close touch with the Trade and Educational Authorities, as well as with other Government Departments concerned.

Constitution of the Aeronautical Research Committee.

40. The Aeronautical Research Committee should include representation of—

- (a) the Department or Departments responsible for (i) naval and military aeronautics, (ii) the regulation of civil aerial transport ;
- (b) the Department of Scientific and Industrial Research, including direct representation of the National Physical Laboratory ;
- (c) the Aircraft Industry ;
- (d) the Imperial College ;
- as well as
- (e) other members of scientific attainments.

The Chairman of the Committee should be a scientist of eminence, and in a position independent of the Government Departments represented on the Committee.

He and the other non-official members of the Committee should receive suitable remuneration.

Functions of the Aeronautical Research Committee.

41. It should be the duty of the Aeronautical Research Committee to devote itself to the advance of Aeronautical Science, and, with this object, in particular—

- (1) to advise on scientific and technical problems relating to the construction and navigation of aircraft ;
- (2) to undertake or supervise such research or experimental work as is proposed to the Committee by the Air Ministry, and to initiate any research work which the Committee considers to be advisable ; to carry out such work itself or to recommend by whom the work should be carried out ;
- (3) to take over complete responsibility for the Air Inventions Committee and for the Accidents Committee ;
- (4) to promote education in aeronautics by co-operating with the Governors of the Imperial College ;
- (5) to assist the aeronautical industry of the country by scientific advice and research, and to co-operate with any Research Association that may be established ;
- (6) to prepare for the approval of the Air Council a scheme of work and estimate of expenditure for the year, and to administer the funds placed at its disposal by the Air Council ;
- (7) to make reports from time to time to the Air Council.

Aeronautical Research Committee to replace Advisory Committee.

42. We propose that the Aeronautical Research Committee should replace the present Advisory Committee for Aeronautics, discharging in the main the functions of that body. On this point it is desirable to refer briefly to the present functions of the Advisory Committee.

43. The Committee was originally appointed to advise the Prime Minister as Chairman of the Imperial Defence Committee, to determine what problems should be studied, and by what methods, and to discuss and offer advice on the solutions. It was the duty of the Committee to superintend the investigations at the National Physical Laboratory, and to advise generally on the scientific problems arising in connection with the work of the Admiralty and War Office in aerial construction and navigation.

Since the inception of the Air Ministry the Committee has reported to the Secretary of State for Air instead of to the Prime Minister, its duties remaining unaltered. The Air Ministry, Admiralty, and War Office were represented on the Committee by officers of high standing, and this close association proved of great value in securing co-ordination of research.

44. The work of the Advisory Committee for Aeronautics is ordinarily carried out through a number of standing Sub-Committees. These Sub-Committees submit monthly programmes of work to the Main Committee, and the results of all the approved investigations are in the first place reported to and discussed by the Sub-Committees.

45. It should be added that the executive control of the staff responsible for carrying out investigations at the National Physical Laboratory rests not with the Advisory Committee but with the Executive Committee of the Laboratory which undertakes to carry them out in accordance with the wishes and advice of the Advisory Committee. The fact that the Chairman of the Advisory Committee also filled the post of Director of the Laboratory facilitated this arrangement.

46. It will clearly be necessary that the Aeronautical Research Committee should have power to appoint Sub-Committees, membership of which should not be restricted to members of the Committee itself. It has been the practice in the past, when appointing such Sub-Committees, to include in their membership representatives of the actual workers engaged in the fields of work under consideration. This practice has been found to be of very great value.

Financial and Administrative Arrangements.

47. In accordance with the decision of the Government, the responsibility for research and experimental work undertaken for the development of aeronautics with money provided by the Government will be shared by the Department of Scientific and Industrial Research and the Air Council.

The Air Council will be responsible generally for work financed directly from funds at their disposal, while the assistance given by the Department of Scientific and Industrial Research will be on lines similar to those applicable in the case of other industries, *i.e.*, by the formation of a Research Association. The Department will also continue to be responsible for the funds required for the work at the National Physical Laboratory.

Where the Aeronautical Research Committee finds it desirable to arrange for specific research or experimental work to be carried out by individual research workers other than those engaged in the central establishments, the necessary arrangements should be made in consultation with the Department of Scientific and Industrial Research, which is responsible for the main State provision for the assistance of research conducted under such conditions.

48. We would urge the importance of the financial arrangements of the Aeronautical Research Committee being put on a basis which will allow an adequate freedom in the allocation of expenditure within the limits of the total sum available.

Co-ordination of the Research and Educational Organisation.

49. We have referred earlier in this Report (Section 14) to the need for close association between the research and experimental work and the strictly academic portion of the higher education. No school for providing this education can be successful unless the students are brought into direct touch with practical problems during their tuition, and unless those engaged in teaching are also engaged in or directing scientific research or experimental design.

50. The arrangements whereby the student will divide his period of post-graduate instruction between work on books and at lectures and practical work at research stations, to which we have already referred, should apply also in regard to the duties of the teaching staff. These should be such as to enable a professor or lecturer to spend part of his time in giving instruction at the Imperial College, while giving the rest to investigations at one of the research centres.

51. As stated in Section 20, the School of Aeronautics should provide advanced instruction as regards aeroplanes, seaplanes, airships and kite-balloons in (1) aerodynamics; (2) aero-engines and methods of propulsion; (3) design, including structure

and materials: (4) instruments, meteorology and navigation. It would follow, therefore, that certain of the professors or lecturers in each of these subjects will discharge double responsibilities, (a) as members of the staff of the Imperial College and (b) as officers of the research organisation directed by the Aeronautical Research Committee.

52. The Interim and Final Reports of Special Committee No. 5 of the Civil Aerial Transport Committee contain much valuable information as to the organisation of teaching and research. One factor of importance which they emphasise is the need for a trained staff to act as a clearing house for the co-ordination and dissemination of aeronautical knowledge in all its aspects. The Central School of Aeronautics should, in our view, serve this purpose.

The functions of the teaching staff of the School may be stated under four distinct, though closely related, purposes:—

- (a) To study, co-ordinate, summarise, apply and extend the knowledge derived from the experimental work carried out by the individual workers at various experimental stations in this country and abroad.
- (b) To stimulate research by indicating what information is most urgently required and what line of attack is likely to prove most profitable.
- (c) To guide and encourage research by constructive criticism based on a careful study of past and current work in this country and abroad.
- (d) To impart this knowledge by personal teaching to a limited number of post-graduate students.

A similar clearing house for current knowledge would be of value in any science, but for aeronautics it is, for the present, essential, for whereas in older sciences—Physics, for instance—the bulk of the experimental data have, throughout the course of generations, crystallised into well-defined laws which form a framework ready to receive any new facts and a criterion by which their accuracy can be estimated, in Aeronautics the facts are the result of the work of the last five or ten years, and the framework uniting them exists only in the minds of the few men who have been personally connected with the process of development.

Before the war the total available knowledge was small, and it was possible for the members of the Advisory Committee to keep all the facts in mind while devoting the majority of their time to other duties. They then provided the necessary co-ordinating factor. This is no longer possible, and the function could best be discharged by the staff of the School working under their Director with a view to co-ordinating and making available all the knowledge in each branch of the work as existing at the moment.

For these reasons it is essential that the permanent staff of the Central School should be adequate both in numbers and in range of experience to the duties outlined above.

53. It has been arranged that the Zaharoff Professor of Aviation should be Director of the School of Aeronautics in the Imperial College. We consider that he ought to have an important voice in the direction of research, not only in the College but at the Central Research Establishment and elsewhere. He would naturally be a member of the Aeronautical Research Committee, and in this way be brought into intimate contact with the investigations in all the stations. The work would occupy his full time. These considerations will no doubt be borne in mind by the Body responsible for making the appointment.

It will also be necessary to have a full-time Professor of Aerodynamics at a salary, say, of 1,000*l*.

54. The engineering questions relating to airships and kite-balloons are of such importance and so distinct as to require the full time of a senior officer who would devote himself to teaching and research, and whose duty it would also be to ensure that special problems relating to these subjects were adequately dealt with in the courses of instruction on aircraft engines and strength of materials. For this purpose we recommend the appointment of a Professor of Airship Construction.

55. The subject of Meteorology, including with it training in navigation and the use of instruments employed in flight, is one of great importance. The position, however, of the teacher of this subject must depend on the action taken with regard to research and inquiry into Meteorological Science generally. We have made provision in the estimates for a teacher in meteorological subjects closely connected with aeronautics who should combine this work with research at one of the experimental stations. His work would be brought into connection with the central meteorological establishment.

We would add that quite apart from the other interests concerned we feel it our duty to press for the establishment of a properly equipped centre of teaching in this subject, the need for which has been felt for some years and is now acute.

56. Our estimate of the numbers and cost of the total establishment at present required for the Department of Aeronautics at the Imperial College is given in Appendix A.

The dual functions of research and education might perhaps be combined as shown below:—

Imperial College.

Research Organisation.

- | | |
|--|---|
| 1. Professor of Aerodynamics | - Aerodynamics Research, Central Research Establishment. |
| 2. Professor or Lecturer on Engines and Methods of Propulsion. | Engine Research Laboratory, Central Research Establishment. |
| 3. Professor or Lecturer on Design | Design Branch of Central Research Establishment or Designer of some Private Firm. |
| 4. Professor of Airship Construction | Research Officer at a central Airship Station. |

Clearly, however, the feasibility of such combinations must depend on the men available, and the above is only put forward as a possible arrangement.

57. It is obvious that this duality of functions can only be maintained on a basis of goodwill and readiness to co-operate between the Imperial College with whom will be vested the appointments in the School of Aeronautics and the Aeronautical Research Committee, but we feel that the details of the method of establishing full co-operation should be left to the two bodies to determine.

Estimated Cost of Educational and Research Organisation.

58. (a) The main item will be the maintenance of the central research establishment at Farnborough. This is, we understand, provided for on an adequate scale in the estimates of the Research Directorate of the Air Ministry. Along with the above should be considered the provision for other work undertaken for the Air Ministry, such as the responsibility for the Air Inventions Committee and the Accidents Committee.

(b) Provision must continue to be made for the expenditure of the aeronautical department at the National Physical Laboratory. The provision made for 1919-20 was 33,000*l.*, and this sum falls on the votes of the Department of Scientific and Industrial Research.

(c) We estimate that the cost of the Department of Aeronautics at the Imperial College, with salaries on the standards of remuneration which obtain in existing departments of the College, together with an allowance for wages of mechanics and cost of laboratory experiments, should amount to about 10,000*l.* a year. (See Appendix A.) Towards this sum the income of the Zaharoff endowment of 25,000*l.* is all that is at present available.

(d) Besides the provision to be made at the Imperial College, provision should be made for Research other than that required specifically for the Air Ministry. The responsibility for this lies already with the Department of Scientific and Industrial Research, who are making grants to individual research workers, amounting during the current academic year to 31,500*l.* (See Section 38 (c) of the Report.)

(e) Provision may also have to be made in future for the development of Teaching and Research elsewhere as well as at the Imperial College. (See Section 1 (c) of the Report.)

(f) The fees of the non-official members of the Aeronautical Research Committee must also be allowed for, but this will be a minor item.

RECOMMENDATIONS.

Our recommendations are as follows:—

I. An Aeronautical Research Committee should be constituted in connection with the Air Ministry.

II. Encouragement should be given to the establishment of an Industrial Research Association for the Aeronautical Industry.

III. The Aeronautical Research Committee should include representation of—

- (a) the Department or Departments responsible for (i) naval and military aeronautics, (ii) the regulation of civil aerial transport;
- (b) the Department of Scientific and Industrial Research, including direct representation of the National Physical Laboratory;
- (c) the Aircraft Industry;
- (d) the Imperial College;
- as well as
- (e) other members of scientific attainments.

The Chairman of the Committee should be a scientist of eminence, and in a position independent of the Government Departments represented on the Committee.

IV. It should be the duty of the Aeronautical Research Committee to devote itself to the advance of Aeronautical Science, and, with this object, in particular—

- (1) to advise on scientific and technical problems relating to the construction and navigation of aircraft;
- (2) to undertake or supervise such research or experimental work as is proposed to the Committee by the Air Ministry, and to initiate any research work which the Committee considers to be advisable; to carry out such work itself or to recommend by whom the work should be carried out;
- (3) to take over complete responsibility for the Air Inventions Committee and for the Accidents Committee;
- (4) to promote education in aeronautics by co-operating with the Governors of the Imperial College;
- (5) to assist the aeronautical industry of the country by scientific advice and research, and to co-operate with any Research Association that may be established;
- (6) to prepare for the approval of the Air Council a scheme of work and estimate of expenditure for the year, and to administer the funds placed at its disposal by the Air Council in accordance with Recommendation VI.;
- (7) to make reports from time to time to the Air Council.

V. The Committee should replace the present Advisory Committee for Aeronautics, and its non-official members should receive suitable remuneration.

VI. The expenditure of the Committee should form part of the Annual Vote taken by the Air Ministry, and the arrangements should be such as to allow adequate freedom to the Committee within the limits of the total sum available.

VII. It is not, in our opinion, practicable at present to establish a School of Aeronautics at more than one institution providing the specialised training required by those who are to direct aeronautical research and the design and construction of aircraft. For this purpose we recommend that a Department of Aeronautics in the Imperial College under the Directorship of the Zaharoff Professor of Aviation should be established for the provision of advanced instruction in Aeronautics generally on the lines indicated in Sections 52 to 56 of our Report. The scheme for the Department should be framed with full regard to the facilities provided in existing Departments of the Imperial College and should be settled in consultation with the Aeronautical Research Committee. It should be left to the Governing Body of the Imperial College and the Aeronautical Research Committee to determine a method of mutual co-operation.

VIII. Arrangements should be made whereby, as far as possible, the officers in charge of the researches at Farnborough and elsewhere should hold positions on the teaching staff of the Department of Aeronautics.

R. T. GLAZEBROOK (Chairman).
 ALFRED KEOGH.
 H. FRANK HEATH.
 F. G. OGILVIE.
 F. HANDLEY PAGE.
 G. HOLT THOMAS.
 J. E. PETAVEL.
 H. T. TIZARD.

J. G. GIBSON,
 Secretary.

12th December 1919.

APPENDIX A.

ESTIMATED COST OF TEACHING STAFF IN THE DEPARTMENT OF AERONAUTICS IN THE
IMPERIAL COLLEGE, WITH COST OF EXPENSES OF LABORATORY WORK.

	£
Zaharoff Professor of Aviation (Director of the School of Aeronautics) - -	1,500
Professor of Aerodynamics - - - - -	1,000
Professor of Airship Construction - - - - -	1,000
Five Teachers (part time) on Design, Materials, Aircraft Engines, Meteorology and Navigation, and Airships at an average remuneration of 400l. each - - - - -	2,000
Four Teachers (full time) at an average remuneration of 375l. - - - - -	1,500
Provision for occasional lecturers - - - - -	500
	<hr/>
	7,500
Mechanics' wages - - - - -	1,000
Expenses of Laboratory Work - - - - -	1,500
	<hr/>
	£10,000

It should be noted that in respect of Meteorology this estimate includes only the cost of the special teaching required in the Aeronautics Department; it does not cover the cost of establishing a centre for meteorological instruction generally.